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A Computer-Controlled x-y Offset Guiding Stage for the MLRS

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ABSTRACT

The MLRS has experienced excellent success in its lunar and artificial satellite laser ranging operations during its many years of operation, in spite of its relatively small "receive" aperture. We continue to strive, however, for a greater volume of data, together with better accuracy and precision. We have just now completed the design, construction, and implementation of a computer controlled x-y offset guiding stage for the MLRS, analogous to the manual one that had been a part of the original 2.7-m lunar laser ranging system on Mt. Locke at McDonald Observatory. In the past we had been hampered by the lack of a satisfactory hardware design which could fit within the very cramped quarters of the MLRS telescope's tailpiece. Recently, with funding support from the U. S. Naval Observatory and the design and construction expertise of DFM Engineering, Inc., a satisfactory instrument has been specified, designed, built, and installed. This instrument will greatly expand MLRS observational opportunities by allowing the observing crews to actively guide on visible off-axis lunar surface features or background stars while the on-axis lunar surface retroreflector targets are in the dark. This paper describes this instrument and its present implementation at the MLRS.

Introduction

The McDonald Observatory Laser Ranging Station (MLRS) is a dual purpose installation (Shelus 1985) which was designed to obtain laser returns from both artificial satellite and lunar surface retroreflector targets. It was originally constructed to replace the NASA Apollo Lunar Ranging Experiment (LURE) system which had been installed on the McDonald Observatory 2.7-m telescope in the late 1960's (Silverberg 1973) and was used up until the mid 1980's. The MLRS is designed around a 0.76-m x-y mounted Cassegrain/Coudé reflecting telescope and a very short pulsed, frequency doubled, 532-nm wavelength, neodymium-YAG laser, with associated computer, electronic, meteorologic, and timing interfaces. The station was initially erected in the saddle between Mt. Locke and Mt. Fowlkes at McDonald Observatory, near Fort Davis, in far west Texas and first became operational in the summer of 1983. It was soon recognized that wind tunnelling effects in and around this saddle site had very serious effects on what astronomers call atmospheric seeing. A new telescope pad was constructed and the MLRS was moved to its present site atop Mt. Fowlkes in early 1988 (Fig. 1).

Since the mid-1980's, the MLRS observing emphasis has been shifting dramatically from the Moon to artificial satellite targets (Fig. 2) but the Moon has always continued to be an important part of its routine operations (Shelus 1987). Also, attesting to the splendid versatility of the MLRS, in a cooperative effort with the CERGA lunar laser ranging facility in France, we are using the Meteosat P-2 geostationary weather satellite in a laser ranging experiment to study the transfer of time at the sub-nanosecond level over intercontinental distances. Most of the MLRS observing systems are transparent to the observer and it is often the case that through the course of a single 8-hour observing shift an observing crew will routinely range to such diverse targets as Topex/Poseidon, ERS-1, Starlette, Ajisai, Lageos, Etalon-1, Etalon-2, MP-2, and the Moon. The

Figure 1

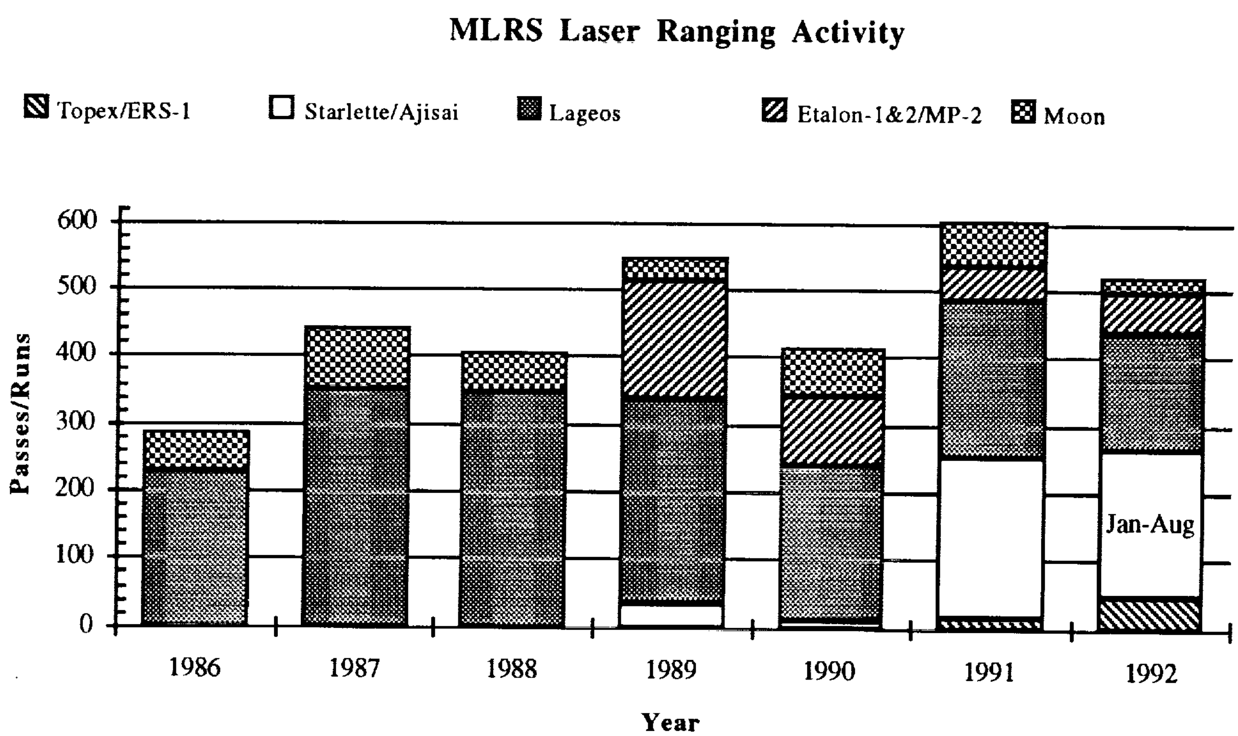

Figure 2

principal differences among all of these observations are the apparent angular speed of the target's motion across the sky and the return signal strength. Of course, low targets move quickly and high targets move slowly. Return signal strength is dictated primarily by the inverse-fourth-power nature of laser ranging. It is extremely important to realize that the return signal strength ratio, neglecting all parameters except the distance, for a near-Earth artificial satellite and the Moon is something like 3×10^{12}. That is to say, it is more than one trillion times more difficult to laser range to the Moon than it is to laser range to, say, Ajisai or Topex/Poseidon.

Increased Data Volume Requirements

In spite of these tremendous handicaps of low signal strength and small "receive" aperture, the MLRS has experienced remarkable success in its lunar laser ranging (LLR) measurements, and the resultant computation of lunar orbit and Earth orientation information therefrom (Whipple et al 1991). However, we are always striving for an even greater number of observations which will, in turn, naturally lead to better accuracy and finer precision. It is evident that we can increase MLRS LLR data volume in at least three ways:

1. spend more time on target;
2. transmit more energy;
3. increase "receive" aperture.

With support from a contract from the U. S. Naval Observatory we have found ourselves in a position to make a viable attempt at implementing the first technique, i.e., spending more time on target, via the design, construction, and implementation of an x-y offset guiding stage for the MLRS.

An Offset Guiding Stage

The concept of an offset guiding stage is one that is commonly used in observational Astronomy and it has surfaced many times during our deliberations about the logical up-grade of the MLRS during the past several years. It is merely the idea of installing an offset guiding stage on the MLRS, analogous to the one that had been in place and in use on the original 2.7-m LLR system at McDonald Observatory. An MLRS x-y offset guiding stage would allow us to routinely guide on a visible off-axis lunar surface feature (or, perhaps, even a star) while the on-axis retroreflector remains in the dark (i.e, it is on the "other" side of the lunar terminator). Not only would there be a much greater number of observing opportunities during the course of a lunation, perhaps, more importantly, ranging data to lunar surface retroreflectors in the dark would be virtually noise free. In our past plannings we had been hampered by the lack of a suitable hardware design which could fit within the very cramped quarters of the MLRS telescope's tail-piece, and the lack of money to actually construct and implement a design if a satisfactory one could be found. Recently, within our interactions with the U. S. Naval Observatory and DFM Engineering, Inc., support has been provided and a new concept has been formulated for just such an MLRS x-y offset guiding stage.

After a very successful series of bid and negotiating sessions, a contract was set up between the University of Texas at Austin and DFM Engineering, Inc. of Longmont, Colorado for design and construction of a x-y stage for the MLRS. Design drawings for the mechanical systems of the stage were received by us in February, 1992. These drawings were reviewed by McDonald Observatory Laser Operations personnel, with support from our McDonald Observatory mechanical engineering colleagues. In general, the overall design was found to be very well thought out and quite workable. A very small number of minor problems and several enhancements were identified during the review. These were conveyed to DFM, Inc. and were incorporated into the final design. Preliminary design drawings for the electrical systems of the

stage were received from DFM, Inc. at the end of March. An internal electrical systems design review which was held at the MLRS during the first week in April. The results of that review were conveyed to DFM, Inc. for implementation. Machining and assembly of the mechanical structures were completed in May at DFM, Inc.. Delivery of the hardware to Austin took place in June and initial testing and shake-down, before its shipment to the MLRS for final installation and implementation, was performed. The instrument was transported to the MLRS at McDonald Observatory in July. After a number of adjustments and relatively minor modifications, installation on the telescope took place at the end of August.

The instrument is a two-axis translation stage (Fig. 3) which mounts directly to the MLRS telescope's back-plate. It provides for the simultaneous mounting of two electronic TV cameras with turning optics to direct the telescope's Cassegrain beam to either of the cameras. The cameras are selectable from within the MLRS operation's trailer via computer control or an auxiliary switch. Each axis is driven by a DC servo motor/encoder combination at speeds in a range 0-8 mm/sec and is directly encoded using digital linear encoders. Positioning of each stage is accurate and repeatable to 5 microns with a travel of more than 125 mm in each axis, centered on the optical axis of the MLRS telescope. The electronics control package includes a dedicated PC-type computer based on an Intel 80386SX processor, a motor controller board inside the PC, together with all of the necessary electronic/computer interfaces and controls. Software provides a closed servo loop between the encoders and the motors and communicates with the external MLRS control computer via a serial port. In addition to the source code, the software deliverable includes the development environment as well, so that future software changes, if necessary, can be accommodated without a need to return to the vendor.

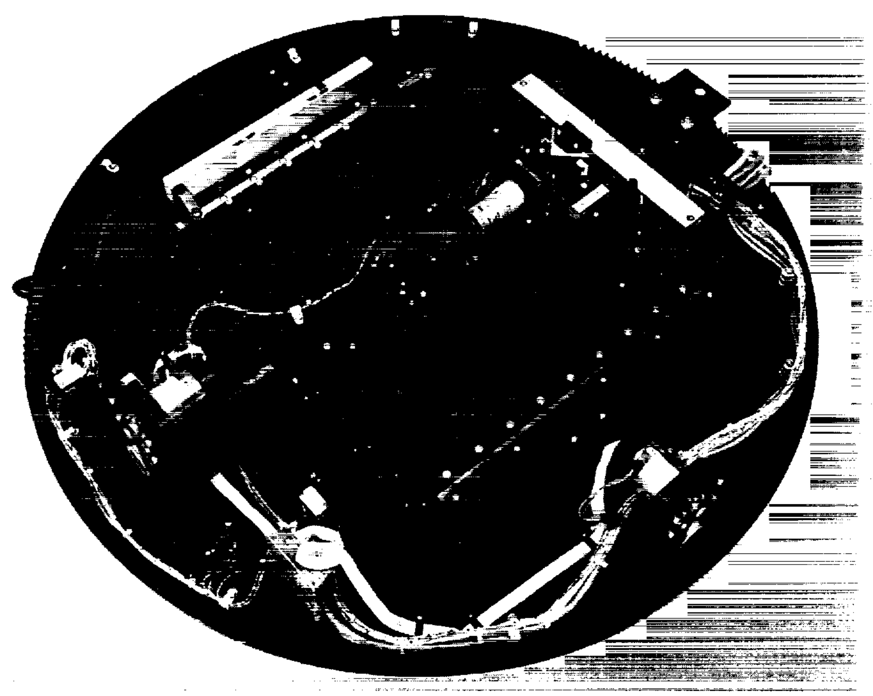

Figure 3

Conclusion

Once in operation, the completed x-y offset guider will have a very positive impact on the quality and quantity of lunar data acquisitions from the MLRS. Sufficient software currently exists to begin immediately the manual operation of the stage at the MLRS. In the coming months and years it is our plan that additional software and hardware will be secured for eventual sem-automatic and completely automatic operation of the stage.

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